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The Effects of Ammonia Containing Wastes on Future Waste Management Operations

WBS No. or Work Package No.: WX63G

Key Words: Ammonia, PUREX, Decladding Waste, Ammonium Nitrate, HEPA Filters, 242-A Evaporator, 216-A-37-1 Crib, Nitrogen Dioxide, AW Tank Farm, AP Tank Farm

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Abstract

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Prepared by (Name and Dept. No.): N. W. Kirch/65400 Nicholas W. Kirch — See Page 2 for Approvals

Date: 1/14 1983

Abstract

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Section

1.0 INTRODUCTION

Waste solutions containing ammonia have been handled for several years in the tank farms. Until recently, few problems have been experienced with the processing of ammonia bearing wastes. Now, improvements in tank design and containment have included the use of forced vessel ventilation systems. These tank ventilation systems have experienced problems due to ammonium nitrate formation within the vent system. Ammonium nitrate, formed from the gas phase reaction of ammonia and nitrogen dioxide, has caused frequent plugging of the high efficiency particulate air (HEPA) filters in the 241-A-702 vessel ventilation system and could cause plugging in other systems in the future.

The source of ammonia in the tank farms in the past has been primarily waste generated from cesium processing at B-Plant with some ammonia generated from complexant degradation reactions in concentrated wastes. The principle source of ammonia during future operations will be neutralized decladding waste generated from the Zirflex process at PUREX. The ammonia concentration of the PUREX decladding waste is significantly higher than wastes now handled on a routine basis in the tank farms. The amount of B-Plant wastes will decrease with the phasing out of cesium processing.

Ammonium nitrate loading of HEPA filters in the primary tank ventilation systems has been the only ammonia related problem experienced during previous handling of ammonia bearing wastes. The potential for other ammonia related problems in the storage tank vapor space, ventilation system, waste evaporator and underground cribs has existed for several years but has never been investigated or evaluated. Upon the resumption of processing at PUREX, relatively high concentrations of ammonia in the decladding waste will be received into the AW and AP Tank Farms on a routine basis. This has warranted a study to identify what problems will be associated with the processing of ammonia wastes, to determine the magnitude of the potential problems and to recommend a course of action to mitigate the problems.

2.0 RECOMMENDATIONS

During future processing of ammonia containing wastes in tank farms, several potential problems could occur. These potential problems include HEPA filter loading, evaporator processing problems, cesium migration and safety problems. The potential problems were investigated, evaluated and a set of recommendations formulated.

Ammonium nitrate loading of the HEPA filters on the PUREX decladding waste tank ventilation systems has the highest probability of occurrence. The projected life of a HEPA filter during decladding waste processing is 50 to 60 days. Although this is shorter than the normal filter life of 1 to 2 years,

it is recommended that no changes be made to the ventilation system to reduce ammonium nitrate loading. The cost of design, construction and operation of any system for extending filter life is far greater than filter changeouts on the projected routine basis.

Several potential safety problems of processing ammonia containing wastes have been identified. The probability of any safety problems is low due to the pungent odor of ammonia and the outside location of the ventilation system. No changes to current practices are recommended.

Evaporator processing of ammonia containing wastes and crib disposal of the process condensate have not experienced problems during previous campaigns with B-Plant wastes. Although problems from future processing of ammonia wastes are not anticipated, the operations should be carefully monitored. The sediment of the 216-A-37-1 crib should be monitored for total gamma activity during evaporator processing of decladding waste to detect any cesium migration through the soil.

3.0 SUMMARY AND CONCLUSIONS

Ammonia containing wastes will be processed in the tank farms during future waste management operations. The principle source of ammonia will be neutralized PUREX decladding waste. Other sources of ammonia will be complexant degradation reactions within concentrated complexant waste and double-shell slurry. Cesium purification waste from B-Plant has been a major source of ammonia in the tank farms during the past. The amount of cesium purification waste will be greatly reduced in the future with completion of cesium processing at B-Plant.

Ammonium nitrate formation in the ventilation system of the decladding waste tanks is a potential problem during future waste management operations. The ammonium nitrate is a product of the gas phase reaction of ammonia and nitrogen dioxide. The nitrogen dioxide is present from releases in decladding waste, concentrated complexant waste and double-shell slurry. The expected formation rate of ammonium nitrate is 0.45 grams per hour causing HEPA filter loading in 50-60 days. Most of the ammonia and nitrogen dioxide will pass through the system unreacted.

Several potential safety risks were identified and evaluated. Ammonia buildup in the tank vapor space and ammonium nitrate buildup on the HEPA filters are projected to be far below any explosive levels. Ammonia releases to the atmosphere are not expected to be a personnel or environmental hazard.

Evaporator processing of ammonia containing wastes has been performed without major problems in the past and analysis of future processing plans indicates no expected problems. The discharge of evaporator process condensate containing ammonia is not expected to cause cesium migration in the 216-A-37-1 Crib.

The most efficient system for reducing ammonium nitrate loading on HEPA filters was found to be a packed tower scrubber. The cost of installation of the scrub system is $100,500 with annual operating and maintenance cost of $30,000 including $32,500 for evaporating scrub water (Ref. 1). A scrub system using an ion exchanger for scrub waste is $250,000 with annual operating costs of $5,000 plus additional costs for periodic recharging of the ion exchange resin and crib disposal (Ref. 1). The annual cost of filter changeouts is expected to be $17,675 including a greenhouse. This is less than a system for extending HEPA filter life.

4.0 FUTURE PLANS FOR AMMONIA CONTAINING WASTES

4.1 SOURCES OF AMMONIA

Ammonia will be prevalent in the wastes stored under future waste management plans. The principle source of ammonia will be the neutralized PUREX decladding wastes generated from the processing of zirconium clad fuel elements. The ammonia concentration of the decladding waste is significantly higher than most waste types previously processed in the tank farms and the decladding waste will be received on a routine basis.

Smaller amounts of ammonia will be contained in the B-Plant cesium purification wastes and will be generated from complexant degradation reactions within concentrated complexant waste and double-shell slurry. The amount of ammonia generated from complexant degradation reactions is expected to be insignificant in comparison to the amount generated from decladding waste and therefore is not considered in this study. The B-Plant cesium purification wastes are isolated from the decladding waste in a different tank farm which is on a different ventilation system. The magnitude of the problems relative to the B-Plant waste has been evaluated and is documented in SD-WM-TI-029, "HEPA Filter Plugging in 241-A-702 Vessel Ventilation System." The decladding waste will be the major source of the ammonia and ammonia-related problems in the tank farms.

4.1.1 Neutralized PUREX Decladding Waste

Current waste management plans call for the decladding waste to be stored in the AW and AP Tank Farms (Ref. 2). Decladding waste, neutralized within PUREX, will be transferred to a double-shell tank where the slurried solution will be allowed to separate into settled solids and supernatant liquor phases. Once the tank has filled with slurry and a phase boundary has been established, the supernate is decanted and evaporated in the 242-A Evaporator-Crystallizer to form double-shell slurry. After decantation, the decladding waste is again transferred into the settled solids tank and the fill-settle-decant cycle is repeated until the tank is almost full of settled solids. The tank is then topped off with a double-shell slurry compatible with the decladding sludge.

During processing of PUREX decladding waste, equilibrium forces will be driving the dissolved ammonia from the solution to the vapor phase. The ammonia released will be mixed with other gases, mostly air, in the tank vapor space and carried away through the primary ventilation system. A small percentage of the ammonia released into the ventilation system will react with nitrogen dioxide present from complexant degradation reactions or released from decladding waste. The ammonium nitrate formed from this reaction will collect on the HEPA filters contributing to the filter loading.

Ammonia not released from the solution to the tank vapor space will remain in the decladding waste supernate phase. The supernate will be decanted and processed through the 242-A Evaporator-Crystallizer. The waste volume of the supernate is reduced by evaporation under vacuum. Ammonia is expected to be completely driven from the concentrated supernatant liquor to the overhead vapor stream. Most of the ammonia in the overheads will be scrubbed in the condensers and collected in the process condensate (Ref. 3). Noncondensables are vented to the atmosphere after HEPA filtration, and the process condensate is released to an underground crib after cesium and strontium levels are reduced in an ion exchange column to within Table II requirements.

4.1.2 Other Ammonia Contributing Wastes

Other wastes to be processed in the AW and AP Tank Farms during processing of PUREX decladding waste will be concentrated complexant waste, double-shell slurry and concentrated customer waste. Complexant degradation reactions within the concentrated complexant waste and double-shell slurry produce several gases including ammonia. The amount of ammonia produced from these reactions is small in comparison to the ammonia released from the decladding waste. The concern with the gases generated from the degradation reactions is that some of the gas produced is nitrogen dioxide which reacts with ammonia to form ammonium nitrate, causing HEPA filter loading. Concentrated customer waste is not expected to generate ammonia, nitrogen dioxide or any other gases that could cause problems for waste management operations.

4.2 QUANTITIES OF AMMONIA

The ammonia concentration of the PUREX decladding waste is expected to be 0.52 M upon receipt to the tank farms (Ref. 4). This is approximately one to two orders of magnitude greater than B-Plant cesium purification waste. Individual batches to decladding waste may be as high as 1.2 M (Ref. 5). The maximum vapor space concentration at equilibrium will be 7.8 mole percent (Ref. 6). The equilibrium conditions will only be reached during a prolonged ventilation system failure. Pilot plant data and previous operating experience indicate that a maximum operational vapor space concentration of 2 mole percent can be expected (Ref. 7).

The double-shell tanks are continuously vented to maintain a slight vacuum within the tank. This is to ensure that any gas leakage will empty into the tank where the gas will be carried through the ventilation system, filtered and exhausted to the atmosphere. The ventilation system concentration of ammonia in the AW and AP Tank Farms during decladding waste processing will be approximately 3,000ppm (Ref. 8), due to air inleakage and dilution from the tanks not containing ammonia.

The concentration of ammonia in the ventilation system will fluctuate with changes in the waste processing activities in the tank farms. Ammonia is expected to be in large excess in comparison to other reactants in the ventilation system, therefore, the fluctuations should not affect ammonium nitrate formation, HEPA filter loading or any other potential problems.

5.0 POTENTIAL PROBLEMS OF AMMONIA CONTAINING WASTES

Several potential problems exist in the management of ammonia containing wastes. Each of the potential problems has been investigated and its magnitude evaluated.

5.1 HEPA FILTER LOADING

Several potential problems exist due to the ammonia contained in waste stored in the tank farms. A high probability of occurrence lies with the problem of HEPA filter loading due to ammonium nitrate formation in the ventilation system of the decladding waste tanks. The rate of filter loading is dependent on the ammonium nitrate formation rate and the residence time within the ventilation system for the formation reaction to proceed. The cause of the ammonium nitrate formation on the HEPA filters is the gas phase reaction of ammonia and nirogen dioxide.

Extensive testing has been performed by the Engineering Laboratories (EL) to understand the formation reaction and develop a method for projecting filter loading based on reactant gas concentrations. The testing simulated projected tank farm operating conditions during decladding waste processing. The purpose of the EL testing was to determine which operating variables have a significant effect on ammonium nitrate formation, to project the filter loading under decladding waste processing conditions and to evaluate the effectiveness of corrective actions for reducing filter loading.

The apparatus used during the EL testing was a scaled down simulation of the primary ventilation system used in the AW Tank Farm. The apparatus consisted of a plexiglass duct with HEPA filtration and a centrifugal fan. Steam injection and heater capability were available to control relative humidity and temperature. The reactant gases were introduced through injection ports upstream of the HEPA filters and the concentrations were controlled by careful monitoring of the injection rate. The total gas flow rate was controlled at the superficial gas velocity (feet per second per area available for filtration) equal to that of the actual ventilation system. The reaction residence time was varied by changing the duct length between the gas injection ports and the HEPA filters.

The ammonium nitrate formed was collected on the HEPA filters installed in the vent system. The amount of ammonium nitrate loading was measured both by the change in differential pressure across the HEPA filter and by HEPA filter weight gain over time. The extent of rection is calculated by the amount of ammonium nitrate collected on the HEPA filter divided by the potential amount of ammonium nitrate if the conversion were 100 percent.

Scoping studies were performed by EL to evaluate which operating parameters had the greatest influence on ammonium nitrate loading of the HEPA filters. The parameters tested were ammonia and nitrogen dioxide gas concentrations and humidity. Kinetic data showed that changes in temperature within the operating ranges of a primary tank ventilation system did not effect ammonium nitrate formation (Ref. 9). The relative humidity of the ventilation systems is controlled by changing the temperature of the system. Changes in relative humidity were shown to have no influence on ammonium nitrate formation. The absolute humidity of an actual tank farm ventilation system can only be increased. Increasing the absolute humidity with steam addition did not affect ammonium nitrate formation.

The parameters that were found to affect ammonium nitrate formation were the reactant gas concentrations and the time for reaction. The ammonia concentration in the primary ventilation system will be in great excess in comparison to the nitrogen dioxide. Changes in the ammonia concentration within the anticipated excess were found not to affect ammonium nitrate formation. Therefore, in the development of the formation rate equation, the ammonia concentration was assumed to be constant and was incorporated into the rate constant. A rate equation was developed based on the initial nitrogen dioxide concentration, the reaction time, and the experimental extent of reaction. The development of the rate equation is given in Reference 9.

The ammonium nitrate formation rate developed from the experimental data was found to be approximately second order with respect to nitrogen dioxide (Ref 9). The general form for the rate equation is:

$$\tau = \frac{1}{k(1-n)} \; C_{NO_2}^{(1-n)} \left[1 - (1-X_{NO_2})^{(1-n)}\right]$$

where τ = Residence time, seconds

k = rate constant, $(\text{moles/liter})^{-1.06} \cdot \text{seconds}^{-1}$

n = reaction order, -

C_{NO_2} = initial nitrogen dioxide concentration, moles/liter

X_{NO_2} = nitrogen dioxide conversion, -

During EL testing, τ and C_{NO_2} were independent variables and X_{NO_2} was the dependent variable. The reaction order, n and rate constant, k were determined from the experimental data. The reaction order was found to be 2.06 and the value of the rate constant used for filter life projections is $292\ (\text{moles/liter})^{-1.06} \cdot \text{seconds}^{-1}$. A plot of projected HEPA filter life for different nitrogen dioxide concentrations and residence times is given in Appendix A.

At startup, two tanks on the AW ventilation system will contain wastes that will release nitrogen dioxide to a maximum of 40 ppm in the tank vapor space (Ref. 6). The ventilation system nitrogen dioxide concentration will be approximately 17 ppm due to dilution air from other tanks. The projected HEPA filter life at startup is approximately 70 to 100 days (Ref. 9). Additional AW tanks will contain wastes that release nitrogen dioxide until FY 1992 when five of the six tanks contain these wastes. The ventilation system nitrogen dioxide concentration at this time will be approximately 33 ppm and HEPA filter life is projected to be 40 days. The average HEPA filter life during the handling of decladding waste is expected to be 50 to 60 days. The maximum HEPA filter loading would occur if all AW tanks contained nitrogen dioxide generating wastes. HEPA filter life under this worst case condition would be one to three weeks.

5.2 SAFETY RISKS

The possibility of ammonia collecting in the decladding waste tank vapor space or ammonium nitrate collecting on the ventilation system HEPA filters to explosive concentrations has been identified as a potential hazard associated with the storage of ammonia bearing wastes. Personnel exposure to ammonia fumes in the tank farm and ammonia releases to the atmosphere are additional concerns during waste management of decladding waste. These potential hazards have been evaluated to determine the magnitude of the potential risk.

The ammonia buildup in the vapor space of the decladding waste tank has been evaluated for the worst case of ammonia vapor in equilibrium with the decladding waste solution at maximum ammonia concentration and maximum temperature. This equilibrium assumption could occur only after an extended ventilation system shutdown. The projected maximum ammonia concentration is 1.2 M and the maximum expected temperature is 50°C. At these conditions, the equilibrium ammonia vapor concentration is 7.8 mole percent (Ref. 6). This is well below the minimum explosive limit of 15 mole percent (Ref. 10) but is above the 5 mole percent limit considered safe for operating mechanical or electrical equipment (Ref. 7). Based on EL and previous operating experience, the vapor space concentration of ammonia is not expected to exceed 2 mole percent during normal operations (Ref. 8).

The ammonium nitrate formed in the primary ventilation system will collect on the HEPA filter causing filter loading and eventual plugging. Although ammonium nitrate is an explosive, it is very insensitive to impact and difficult to detonate (Ref. 11). The ammonium nitrate collected on the HEPA filters is not susceptible to explosion because the loading density will not sustain a detonation. The ammonium nitrate loading density of a filter considered plugged is 1/30 of the density required to sustain a detonation (Ref. 12).

Personnel exposure to ammonia, due to the neutralized decladding waste stored in the tank farms, has been identified as a potential safety risk. Rockwell has set a 25 ppm threshold limit value for ammonia in a work atmosphere (Ref. 13). The threshold limit value represents a condition under which nearly all workers may be repeatedly exposed for usually an eight hour period on a day-to-day basis without any adverse effects. The expected maximum tank vapor space concentration is 2 mole percent (Ref. 7) and the expected maximum ventilation system concentration is 3,000 ppm (Ref. 8). Both these concentrations are within contained systems. The AW primary ventilation system is outside and the ammonia will be vented through a 15' stack before any personnel exposure is possible. Personnel exposures to dangerous levels of ammonia is unlikely because the pungent odor of ammonia warns of concentrations far below the dangerous levels.

The gases contained in the primary ventilation system will be released to the atmosphere after HEPA filtration. The ammonia concentration upon release is expected to be approximately 3,000 ppm. Ammonia is highly soluble in water and breaks down readily in the environment. No environmental release limits exist and the ammonia from the decladding waste tank ventilation system is not expected to be an environmental problem.

5.3 242-A EVAPORATOR-CRYSTALLIZER PROCESSING

The supernatant liquor phase of the neutralized PUREX decladding waste will be processed through the 242-A Evaporator-Crystallizer to produce double-shell slurry. The ammonia concentration of the decladding waste supernate will be higher than any waste previously processed through the evaporator on a

routine basis. Potential problems in the 242-A Evaporator are the buildup of ammonia vapor to dangerous levels, ammonium nitrate loading of the vessel vent system HEPA filters, ammonia odor problems in the evaporator support facilities and ammonia stripping of cesium in the condensate ion exchange column.

The vacuum evaporation process in the 242-A Evaporator should provide a significant driving force for ammonia leaving the decladding waste supernate solution. In equilibrium with aqueous ammonium hydroxide solution, the presence of water vapor in the ternary gas mixture (air-ammonia-water vapor) precludes the formation of a flammable gas mixture above 44°C (111°F) (Ref. 10). The normal operating temperature of the evaporator is 54°C (129°F) (Ref. 14) at which flammable mixtures of ammonia, air and water vapor will not be formed.

The ammonia driven from the decladding waste supernate solution by the vacuum evaporation process will be carried with the overheads to a series of three condensers. Most of the ammonia will be scrubbed from the vapor phase by the process condensate. Some of the ammonia will pass through the condensers as vapor and after HEPA filtration, be vented to the atmosphere.

Two potential concerns of the gas phase ammonia in the evaporator overheads are that the free ammonia will react to form ammonium nitrate and collect on the HEPA filters or pass through the ventilation system unreacted and be drawn into the support facility ventilation system. A hazard review team reviewing the ammonium nitrate filter loading problem viewed it as a nuisance rather than a safety hazard (Ref. 15). During previous evaporator campaigns with ammonia bearing wastes, only small amounts of ammonium nitrate were collected in the ventilation system (Ref. 16). Odor problems were experienced during some ammonia bearing waste campaigns in the 242-S Evaporator. The exhaust stack has been modified to prevent exhaust gases from being drawn into the building ventilation system at 242-S and 242-A (Ref. 17).

The process condensate from the evaporator is routed through a zeolon ion exchange column for cesium removal before being discharged to the 216-A-37-1 crib. A potential problem in the operation of the ion exchange column is that ammonium ions may compete with cesium and strontium ions for sites on the resin. The presence of ammonium ions in the process condensate could reduce decontamination factors in the column to the point that the process condensate does not meet the release limits for disposal in a crib. The cesium ions have a much stronger affinity for zeolon resin than ammonium ions. The problem of ammonium ions eluting cesium from the resin should only occur if the ammonium is in high concentrations (2-3M). The process condensate should be monitored for gamma and beta activity before release to the crib and if cesium elution is a problem, the ion exchange column may possibly be bypassed and the condensate still remain within release limits (Ref. 14).

5.4 216-A-37-1 CRIB DISPOSAL

The process condensate from the concentration of decladding waste supernate in the 242-A Evaporator will be discharged to the 216-A-37-1 crib. The soil in the crib acts as a natural ion exchange system, removing cesium as the waste water migrates toward the water table. During processing of decladding waste supernate, the condensate released to the crib may have a high ammonia concentration and may compete with cesium for ion sites within the soil. Cesium has a higher affinity for the sites and should not migrate through the soil. Monitoring of the sediment for total gamma activity has been recommended for the 216-A-36B crib which handles ammonia scrubber wastes from PUREX. The same monitoring should be performed in the 216-A-37-1 crib during evaporator processing of decladding waste supernate.

6.0 SOLUTIONS TO POTENTIAL PROBLEMS

6.1 HEPA FILTER LOADING

Ammonium nitrate will be formed in the primary ventilation system of the PUREX decladding waste tanks. The formation rate is projected to be an average of 0.45 grams per hour and HEPA filter life is expected to average 50 to 60 days over the life of the tank farm. Under normal waste management operations, where ammonium nitrate is not formed, HEPA filter life is 1 to 2 years. Because of the time, cost, and personnel exposure associated with changing plugged HEPA filters, methods for extending HEPA filter life were investigated and evaluated.

An extensive literature, vendor and manufacturer search was performed to determine alternatives to routine HEPA filters changeouts on a high frequency (Ref. 18). The purpose of the search was to determine what technologies are available for extending the HEPA filter life so that an evaluation of feasibility, effectiveness and cost can be performed.

The investigation for methods to extend the HEPA filter life yielded several different systems with different technologies. The most prevalent methods for ammonium nitrate removal are based on water scrubbing of the gas stream or prefiltration of the gas stream for particulate removal. Some other suggested methods for extending HEPA filter life include ammonium nitrate removal by pyrolysis, catalytic decomposition, absorption by a selective capture agent, cyclones and electrostatic precipitation or reactant gas removal by cold trap and selective distillation.

Several of the suggested methods involve the use of untested technology that would require a great deal of development before any application can be made. Pyrolysis, catalytic decomposition, and selective absorption of ammonium nitrate or the rectant gases have not been demonstrated as feasible

technologies for reducing the ammonium nitrate loading of HEPA filters. The cost of exploring these technologies would be very high and the effectiveness of the system would not be known until after development.

Ammonium nitrate particulate removal by a cyclone or an electrostatic precipitator has been suggested as a potential method for extending HEPA filter life. The off-the-shelf cyclones are designed for very large airflows with relatively large particles (>10μ). Processing the small ammonium nitrate particles (<1μ) seen in the primary ventilation system causes the efficiency to drop off dramatically. Electrostatic precipitators are also designed for higher airflows and larger velocities than experienced in the ventilation system. The efficiency is not high enough to significantly reduce HEPA filter loading.

Ammonia and/or nitrogen dioxide removal by cold trap and selective distillation has been suggested as a means of reducing ammonium nitrate formation. The development, equipment, and operating costs of such a system would be very high and the effectiveness is questionable.

The two methods that appeared most feasible and cost effective for reducing ammonium nitrate filter loading were prefiltration of the gas stream and water scrubbing of the gas stream. These two methods were tested by EL for effectiveness in reducing filter loading.

The prefilter and wet scrub systems were tested separately in the EL ventilation system mock up. The placement of the systems were upstream of the HEPA filters, and modeled after the actual AW placement and residence time. The prefilter systems and wet scrub systems were each tested under projected AW Tank Farm operating conditions and were compared against the base case loading without any system for reducing the filter loading.

Three different types of prefilters were tested, each with a different filter medium. The systems tested were a deep bed fiberglass filter, a coated paper filter and a HEPA filter. The prefilter did collect ammonium nitrate but the HEPA filter downstream also experienced ammonium nitrate loading. The HEPA filter loading was caused by additional ammonia and nitrogen dioxide reacting after the prefilter. The most efficient prefilter was the HEPA filter which reduced downstream HEPA filter loading by 66% (Ref. 9).

The most effective method for extending HEPA life is to wet scrub the gas stream so that ammonium nitrate and the reactant gases are removed. An irrigated mesh pad scrubber reduced ammonium nitrate filter loading by 85% (Ref. 9). A packed tower using pall rings was tested and reduced HEPA filter loading by 82%. Further reduction in loading could be expected by optimizing the design of the packed tower. The optimized design of a packed tower system was developed for the cost analysis.

Two packed tower scrub systems were developed so that a cost comparison between wet scrubbing and routine filter changeouts could be made. Both systems utilized an 8.5 ft high column with a 3 ft diameter and packed with 3/4" ceramic Raschig rings. Both systems also utilized a 50 gpm, 20 ft head pump for recirculation of scrub water. The difference between the two systems was that one had a 6 ft high by 1 ft diameter Zeolon-900 ion exchange column and a 5,000 gal holding tank for treating the waste water before crib disposal and the other system sent waste water directly to a double-shell tank for evaporation. The cost of the installed systems (including piping, valving, heat trace, insulation, utilities and a concrete pad) is $250,000 with the ion exchanger and $100,500 without (Ref. 1).

Costs in addition to the installation costs would be incurred with the operation of a wet scrubber system. Yearly maintenance costs have been estimated at $2,000. Operator support would be required for the scrub system at an annual estimated cost of $3,000. The cost of disposal of approximately 130,000 gallons of water at $0.25 per gallon is required if the ion exchange system is not included. If the ion exchanger is included periodic recharging and crib disposal needs to be included in the operating cost.

Changing out HEPA filters has been estimated to cost $2,525 per changeout including installing and removing a greenhouse. Without the greenhouse, the cost is $1,630 per changeout. At the projected HEPA filter life of 50-60 days, annual changeout costs would be $17,675 with a greenhouse and $11,410 without a greenhouse. The life-cycle cost of changing HEPA filters on a routine basis appears to be much less than either wet scrub system.

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APPENDIX A

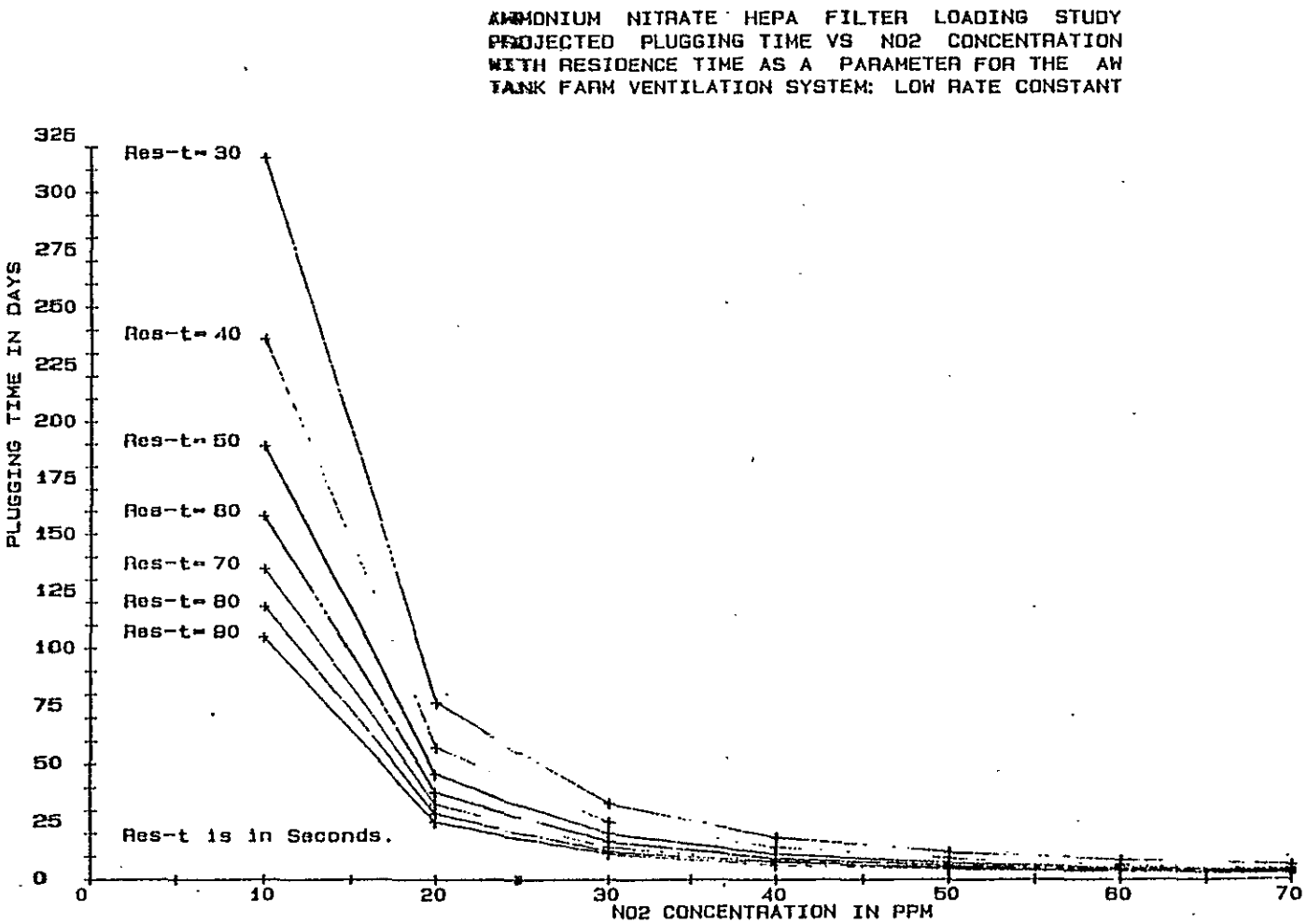

FIGURE 3-12. (Reference 9.)

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